THE USE OF REMOTE CAMERAS TO MONITOR TRAFFIC ACTIVITY

A Thesis

by

MANUEL ANTONIO PADILLA

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee,	Roel R. Lopez
Committee Members,	Nova J. Silvy
	Russell Feagin
Head of Department,	Michael P. Masser

December 2013

Major Subject: Wildlife and Fisheries Sciences

ABSTRACT

Remote Infrared-triggered cameras are commonly used in wildlife management research. Cameras are used for population estimates, identification, and behavioral observations. Road systems are an important factor in wildlife management research and are monitored using a variety of methods. The purpose of this study was to use infrared-triggered cameras as a novel, cost efficient tool to measure traffic activity for use in wildlife management. I conducted a pilot study in order to determine which traffic monitoring system would be the most accurate and cost effective. This pilot study was conducted on a heavily trafficked road comparing Cuddeback and Reconyx cameras to pneumatic road counters and manual observation. I used the Cuddeback Attack© digital infrared-triggered cameras in a field study at Camp Bullis, San Antonio on three different road types (Paved, gravel, and trail). Eighteen cameras collected a total of 58,658 vehicle observations over the course of 12 months. I determined that vehicle observations made by month and hour were dependent on each of the road types by Pearson's Chi-squared test ($P < 0.0001$) with paved roads having the highest observations. Traffic activity was highest during temperate months (March/October) and hours (900-1000). The results can be used at Camp Bullis to determine when and where to best conduct population estimates on their white-tailed deer population as paved roads may bias the estimate. Overall, vehicle monitoring by camera may provide researchers with a baseline on how traffic may or may not affect convenience sampling bias on wildlife migration, distribution, or nesting habits.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Roel Lopez, for giving me the opportunity to work on this project. My thanks go to committee members Dr. Silvy and Dr. Feagin for their willingness to be on my committee and provide support to my research.

Thanks also go to my friends and colleagues at Camp Bullis who helped make this possible. Frank Cartaya, Chad Grantham, and Jared Beaver were a huge help during my time at Camp Bullis. Thanks to Felix Arnold and John Tomecek for their support during the process. Finally, Brian Pierce who supported, guided, and encouraged me both in my research and personally with great philosophical insight.

TABLE OF CONTENTS

Page

ABSTRACT ii

ACKNOWLEDGEMENTS iii

TABLE OF CONTENTS iv

LIST OF FIGURES v

LIST OF TABLES vi

CHAPTER I INTRODUCTION 1

Goals and Objectives 4
Study Area 5

CHAPTER II PILOT STUDY 7

Materials and Methods 7
Results 8
Discussion 8

CHAPTER III FIELD STUDY 10

Materials and Methods. 10
Results.. 12

CHAPTER IV CONCLUSION 18

Management Implications. 18

LITERATURE CITED 20

LIST OF FIGURES

Page

Figure 1 Study area with camera locations (numbered) and 3 different road types (red, trail; blue, gravel; green, paved), Camp Bullis, Texas, 2012……………......11

Figure 2 Total vehicle counts by road type at Camp Bullis, Texas from March 2012 to March 2013...………………………..……………..…..…………13

Figure 3 Total vehicle counts by month and road type at Camp Bullis, Texas from March 2012 to March 2013...…..……………………………………….. 14

Figure 4 Total vehicle counts by month at Camp Bullis, Texas from March 2012 to March 2013...……...………………………………………………. 15

Figure 5 Total vehicle counts by 24-hour period and road type at Camp Bullis, Texas from March 2012-March 2013..…………………………………..… 16

Figure 6 Total vehicle counts by hour at Camp Bullis, Texas from March 2012-March 2013..…………………………………………………………….. 17

LIST OF TABLES

Page

Table 1 Vehicle observations by method 8

CHAPTER I

INTRODUCTION

Wildlife researchers (Kucera and Barrett 1993, Garrison et al. 1999, Swann et al. 2004, Locke et al. 2012) have used remote photography methods for over 50 years. Early camera systems (Gysel and Davis 1956, Dodge and Snyder 1960, Cowardin and Ashe 1965) were custom built to match the needs of their respective wildlife projects. The cost of camera equipment, film, film development, maintenance, and data management were major drawbacks in earlier systems (Kucera and Barrett 1993). However, recent innovations in camera technology have created renewed interest in the use of cameras for wildlife management. Smaller batteries with longer charge life decrease maintenance frequency and allow for deployment in extreme environments (Cutler and Swann 1999). The advent of digital image processing makes it possible to store thousands of pictures or video images (Brown and Gehrt 2009, Newbery and Southwell 2009) without the inherent cost or delay necessary with film based images. As a result, many wildlife management techniques now utilize digital photography on a routine basis.

The addition of remote infrared triggering has revolutionized camera use within wildlife management. Remote infrared-triggered cameras have been used for population estimates on white-tailed deer (*Odocoileus virginianus*), bobcats (*Lynx rufus*), bears (*Ursus* spp.), and many other species (Jacobson et al. 1997, Heilbrun et al. 2006, Roberts et al. 2006, Mathews et al. 2008). This technique is less intrusive than capture-recapture methods, and more cost effective and reliable (Jacobson et al. 1997). Cameras have been used to identify individuals within a species using distinct markings (Heilbrun et al. 2003). Remote cameras are effective at collecting data that may be difficult to obtain otherwise. This includes nesting ecology or predation events that can now be precisely timed and identified (Cutler and Swann 1999, Richardson et al. 1999, Ribic et al. 2012). Traditional methods for nesting predation using physical evidence do not account for multiple or partial events and the timing as found in Dreibelbis et al. (2008). Rare, nocturnal, or skittish animals may be surveyed using remote cameras to provide information on their distribution or even behavior (Crooks et al. 2008). Cameras provide data in geographically isolated areas or where innovation might help meet the research demands (Lopez and Silvy 1999, Thome and Thome 2000). The variety of uses for remote photography in wildlife research is increasing as technology allows for smaller cameras that can provide even more data and storage capacity (Locke et al. 2012).

Road systems and traffic data are important factors in wildlife research. Road systems bias research due to their nonrandom infrastructure and the effect traffic may have on wildlife (Anderson 2003, Buckland et al. 2001, Roberts et al. 2006). Population road-surveys are assumed to be influenced by traffic, but there is little data to support this assumption (Progulske 1964, Beier 1990). Traffic data are already collected through a number of different ways by governmental agencies for use in infrastructure planning. Various sensors and pressure plates are used for larger freeway traffic, but more inexpensive, practical means can be used for rural or 2-lane roads. Manual observation is relatively simple but requires labor and time restrictions such as personnel limitations

(Skszek 2001). The National Park Service uses an automatic traffic recording system with pneumatic road counters in order to measure traffic patterns (Liggett 2008). Pneumatic road counters are common, but the amount of data collected is limited to axle counts and speed. Although used in a variety of studies, the accuracy of these devices has come into question (McGowen and Sanderson 2011). Infrared devices or video detection systems are also used if they can be positioned precisely. Video detection systems allow for more data collection as well as being extremely cost effective (Wang et al. 2008, Deb and Rajiv 2012). Large road networks can be monitored using an extensive camera networks connected by broadband wireless. These communication networks can then be analyzed from a remote location to assess traffic activity over large areas (Huang and Buckles 2012).

Roads have been found to affect wildlife distribution, behavior, and dispersal (Butler et al. 2005, Dickson et al. 2005, Laurian et al. 2008, Long et al. 2010). Roads may also have a significant detrimental impact on endangered species (Cypher et al. 2009) or reduce the potential for ideal nesting sites (Pitman et al. 2005). Road traffic information may be used to plan wildlife research to either account for these factors or prevent against damage to road systems (Curtis and Jensen 2004). Distance sampling from the roadway, as a population estimation technique, is a critical tool used in wildlife research (Anderson 2001, Buckland et al. 2001). This type of sampling, known as convenience sampling, may not necessarily be representative. Sampling from convenient locations such as roads may introduce bias and weaken statistical claims (Anderson 2003). More or less traffic on a road can skew data collected on or around that road. Knowledge of traffic density on road systems would help eliminate bias when using these techniques (Butler 2005, Erxleben et al. 2011). A measure of relative road use may be useful in this type of research.

This study aims to use common remote infrared-triggered cameras as a method for measuring traffic activity for use by wildlife managers. I evaluated a novel approach to measuring traffic activity through the use of infrared triggered cameras. This method has potential as infrared triggered cameras are cost effective, versatile, and commonly used in wildlife research (Locke et al. 2012). Traffic data, including the type of vehicle, date, time, and direction of travel, may be shown to influence wildlife activities, and therefore, may be used to assess the impact of traffic patterns on animal behavior and habitat use. The aim of this study was to use infrared triggered cameras to accurately measure and monitor traffic activity, in order to assess the influence of traffic density on habitat use. Specifically, I used infrared triggered cameras to measure traffic density on 3 road types over a 1-year period as part of ongoing study into the impact of convenience sampling on wildlife abundance estimation.

GOALS AND OBJECTIVES

The objectives of my study were to:

1. Determine a cost-effective method of collecting traffic activity data (Pilot Study).
2. Assess 3 different road types in order to be able to differentiate their relative traffic density (Field Study).
3. Determine impact of traffic density on convenience sampling bias depending on road type (Field Study).

STUDY AREA

Camp Bullis Military Training Reservation is located northwest of San Antonio, Texas. The military installation has an area of 11,823 ha. The area is an ecotone of the Blackland Prairies, Edwards Plateau, and South Texas Plains biomes (Gould 1969). Mean annual temperature is 20º C with monthly averages ranging from 11º C in January to 28º C in July. Average rainfall is 74 cm per year with higher than average rainfall during the year of the study (99 cm). The topography consists of hilly terrain that ranged from 300–450 m above sea level. The area is sectioned by the Cibolo, Salado, Lewis Valley, and Leon creeks. These creeks are intermittent and have their own respective drainage basins. The central area is enclosed by the drainage basins of Cibolo Creek on the northern boundary, Lewis Valley Creek in the south central portion of the base, and Salado Creek along the western and southern boundaries. Limestone makes up the majority of the local soils (Taylor et al. 1966). Three major formations within the study area are Buda, Glen Rose, and Edwards Limestone formations. The central portion of the installation is mainly shallow Tarrant-Brackett association soils that surround the road system. Drainage basins are covered with Crawford and Bexar soils, older alluvium deposits of the Krum complex, Trinity-Frio soils, Lewisville silty clay, and Patrick soils in the floodplains.

Main vegetation species in the study area limestone soils are Ashe juniper (*Juniperus ashei*), plateau live oak (*Quercus viginiana*), and Texas persimmon (*Diospyros texana*). Ashe juniper, cedar elm (*Ulmus crassifolia*), sycamore (*Platanus occidentalis*), and Texas persimmon also thrive along the creek bed soils (Van Auken et al. 1979). Plant communities in the respective soils have been shown to have no important differences in composition between soil types (Van Auken et al. 1980). Hilltops and hill slopes contained evergreen deciduous forest with Spanish oak (*Q. texana*), Lacey oak (*Q. glaucoides*), Ashe juniper and Texas persimmon (Van Auken et al. 1981). Typical Edwards plateau vegetation ran alongside the road network.

Camp Bullis had a vast road system that allows the military access to critical training areas. The study area was comprised of a road network with 3 types of roads: paved (asphalt for increased traffic), improved gravel (roads with gravel laid down), and trails (dirt trails for use by vehicles). The road network within my study area totaled 30.8 km in length. Paved roads were 34% of the study area with a length of 10.4 km. Improved and trail roads both made up 33% of the road network with 10.1 km and 10.3 km lengths, respectively.

CHAPTER II

PILOT STUDY

MATERIALS AND METHODS

A pilot study took place on 10 and 15 November 2011 between 1430 and 1700 hours. The location was on a main traffic route through Camp Bullis in order to test the accuracy of different methods. The main traffic route has vehicle convoys at speeds that are comparable to the top speeds reached on the 3 different road types. Traffic activity was collected using 3 separate digital infrared-triggered cameras, 1 pneumatic road counter, and a manual observer. Game cameras were placed approximately 1 m from the ground using a constructed wooden platform and 2 m from the road. All cameras faced north at an angle of 30 degrees off parallel from the road as directed by the instruction manual. A Reconyx© (Reconyx Inc., Holmen, Wisconsin) game camera was set to take 3 pictures on a 0.2-second delay. Two Cuddeback Attacks© (Cuddeback; Non-typical Inc., Park Falls, Wisconsin) were placed on different settings to maximize vehicle captures. One Cuddeback was set to only take pictures with a delay of 15 seconds between each picture. Another Cuddeback was set to take pictures along with a 30-second video and a 15-second delay. All of the game camera data were collected using 2GB SD cards. A pneumatic road counter (Diamond Traffic Products, High Leah Electronics Inc., Oakridge, Oregon) was placed across the road. An observer recorded traffic activity manually on a notepad sitting in a chair 3–4 m away from the paved road for the entirety of the pilot study. Only one road type was tested as the limiting factor for recording vehicle data is traffic speed too fast to be captured on camera. Data were then compared to the total number of vehicles manually observed.

RESULTS

I used the count of vehicles from manual observation as a baseline for comparison with camera data. The Cuddeback Attack© camera set to take pictures but not video recorded 41% fewer vehicles than manual observation over the 2-day period (Manual observation, *n* = 422 vehicles; Cuddeback [pictures only], *n* = 249 vehicles). The Cuddeback camera set to record pictures and video observed 25% fewer vehicles than manual observation over the 2-day period (Cuddeback [pictures and video], *n* = 316 vehicles). The Reconyx© camera observed 10% fewer vehicles than manual observation over the 2-day period (Reconyx, n= 378 vehicles). The pneumatic road counter observed 3% more vehicles than manual observation over the 2-day period (Pneumatic road counter, n= 446; Table 1).

Table 1. Vehicle observations by method.

	Manual observation	Cuddeback – pictures	Cuddeback – pictures and video	Reconyx	Pneumatic road counter
Day 1	208	145	166	206	224
Day 2	214	104	150	172	222

DISCUSSION

The pilot study was meant to provide a baseline estimate of how each camera set up would work in the field. Results allowed me to choose the camera system with the most accurate number of observations of vehicles for the cost. A similar number of vehicles were manually recorded both days due to the observations taking place during the same hours. The Cuddeback© set to take only pictures was outperformed by the one set to take pictures and video according to the results of the pilot study. This was due to the video recording immediately following the picture capture. Video allowed for observations to be captured for the 30 seconds following a picture. The vast difference on the second day of observations between the 2 camera types was due to an increase of vehicles "in a row" or immediately following one another. This was a common occurrence on Camp Bullis as military convoys travel together to perform operations. Pictures and video more accurately capture this scenario.

The pneumatic road counter recorded more vehicle observations than there were. This probably occurred because road counter uses axle counts to tabulate traffic. Multiple axles result in double counts. Military vehicles often have multiple axles on transports or troop transports. The Reconyx© camera was the most accurate recorder of traffic activity. It was extremely sensitive to movement, took multiple pictures, and had the shortest delay. The cost of this camera was too high (approximately $650) compared to the relatively inexpensive Cuddebacks© (approximately $200) to employ in the field study. The Cuddeback© set to take pictures and video was not only accurate, but it allowed more data to be collected than the pneumatic road counter. Data such as type of vehicle, direction, time, and date was critically important to the field study.

CHAPTER III

FIELD STUDY

MATERIALS AND METHODS

Data were collected on traffic activity within Camp Bullis from March 2012 to March 2013 using Cuddeback Attack© digital infrared-triggered cameras. Environmental variables remained relatively uniform throughout the study. Eighteen cameras were placed along 3 different road types: paved, improved, and trail (Fig. 1). These cameras were set to the specifications determined in the pilot study: 1 picture followed by a 30-second video on a 15-second delay. All cameras were placed in a Cuddesafe© (Cuddeback; Non-typical Inc., Park Falls, Wisconsin) to protect from theft, weather, etc. The Cuddesafes were all welded onto steel fence posts that were placed approximately 2 m from a road. Cameras were placed inside the Cuddesafes which were 1 m from the ground and pointed 30 degrees off parallel from the road. Data were downloaded weekly using 2GB SD cards. The vehicle observation data were summarized and analyzed using JMP statistical software (JMP; SAS Institute Inc., Cary, North Carolina). I ran a Pearson's Chi-square analysis of vehicle observations of hour and month by road type to test for independence.

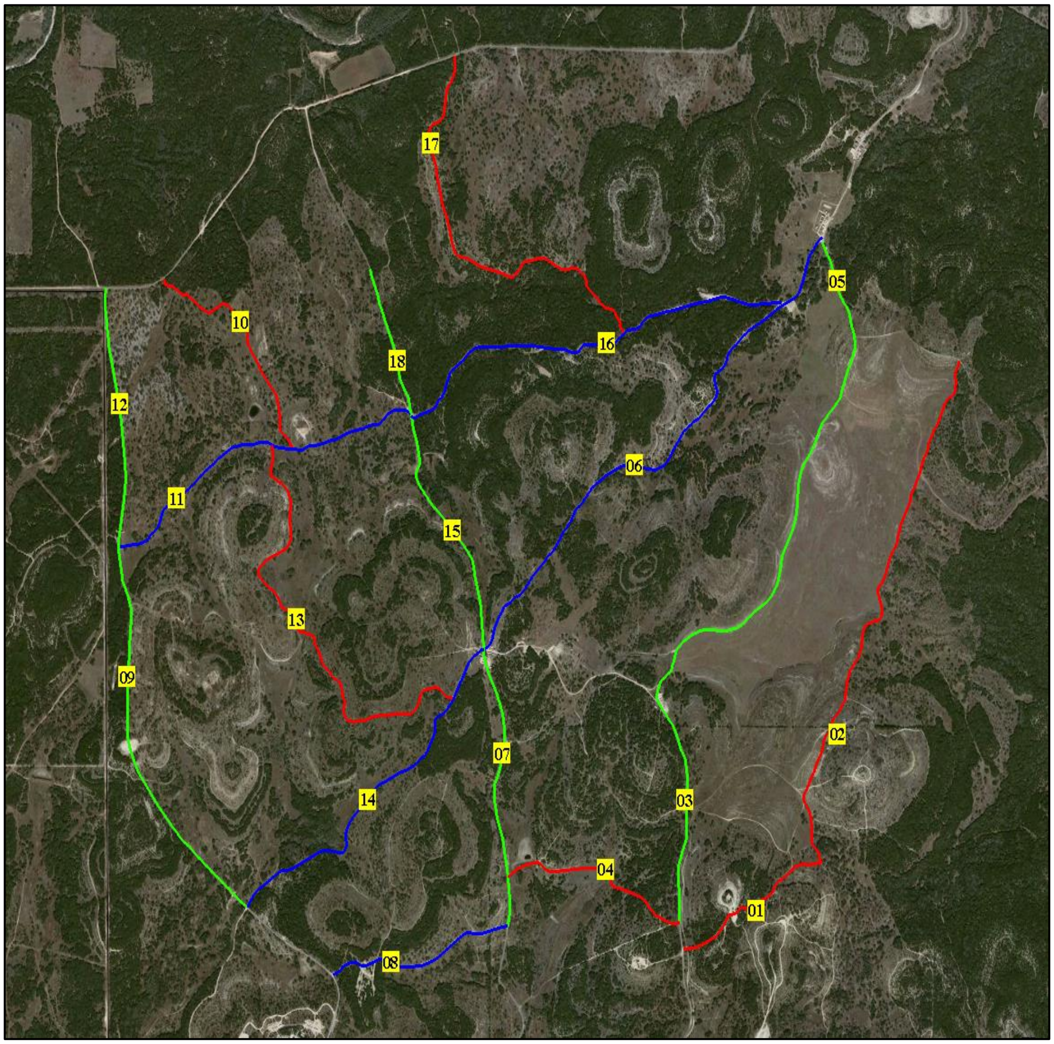

Figure 1. Study area with camera locations (numbered) and 3 different road types (red, trail; blue, gravel; green, paved), Camp Bullis, Texas, 2012.

RESULTS

Over the course of 12 months 58,658 vehicles were observed at all 18 camera stations. Paved roads had the highest vehicle occurrence at 49,812 (84.9%). Gravel and trail roads had vehicle counts of 7,689 (13.1%) and 1,157 (2.0%), respectively (Fig. 2). Vehicle observations by month were found to be dependent on different road types using Pearson's Chi-squared test ($P < 0.0001$; Fig. 3). March was the month with the highest vehicle observations with 8,377 (14.3%), and July was the month with the lowest vehicle observations with 3,023 (5.2%) (Fig. 4). Vehicle observations by 24 hours were found to be dependent on different road types using Pearson's Chi-squared test ($P < 0.0001$; Fig. 5). Traffic activity was highest during the hours 0900, 1000, and 1100 with observations of 5,671 (9.7%), 6,498 (11.1%), and 5,580 (9.5%), respectively. Traffic activity was lowest between 0200, 0300, and 0400 hours with observations of 182 (0.3%), 127 (0.2%), and 167 (0.3%), respectively (Fig. 6).

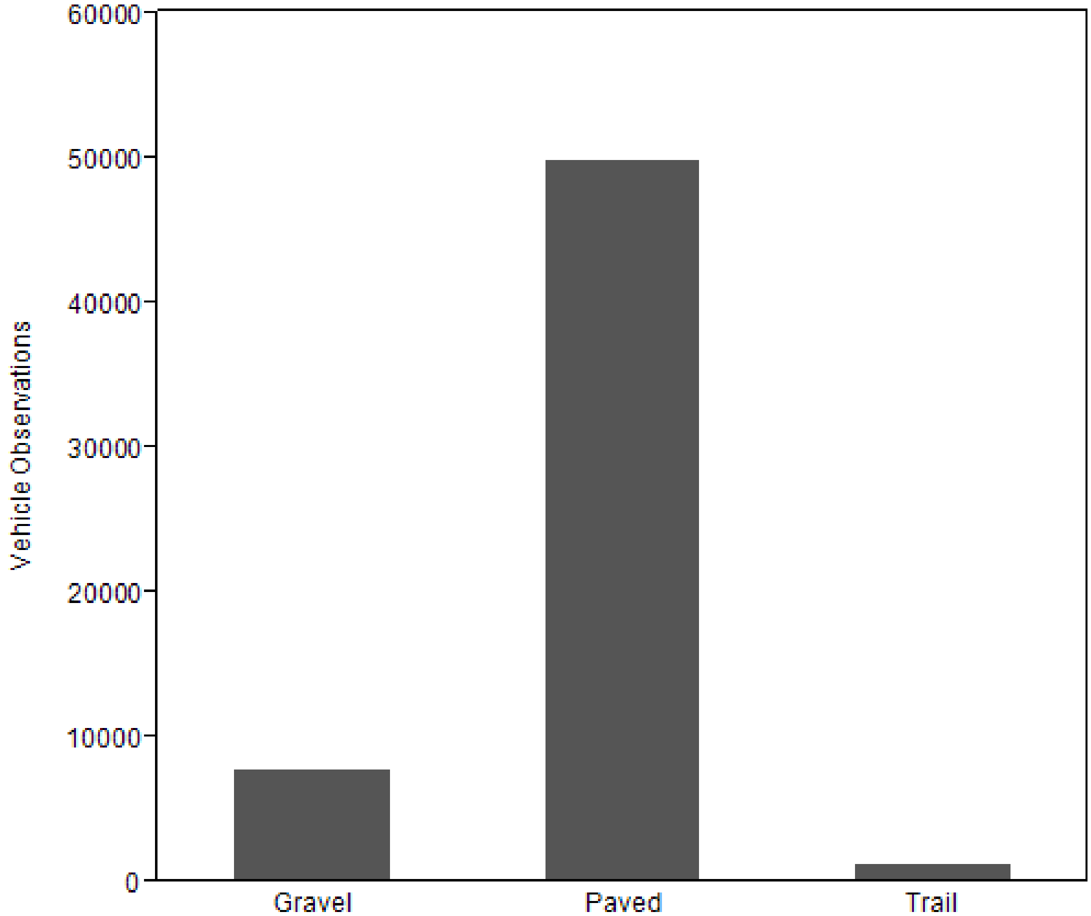

Figure 2. Total vehicle counts by road type at Camp Bullis, Texas from March 2012-March 2013.

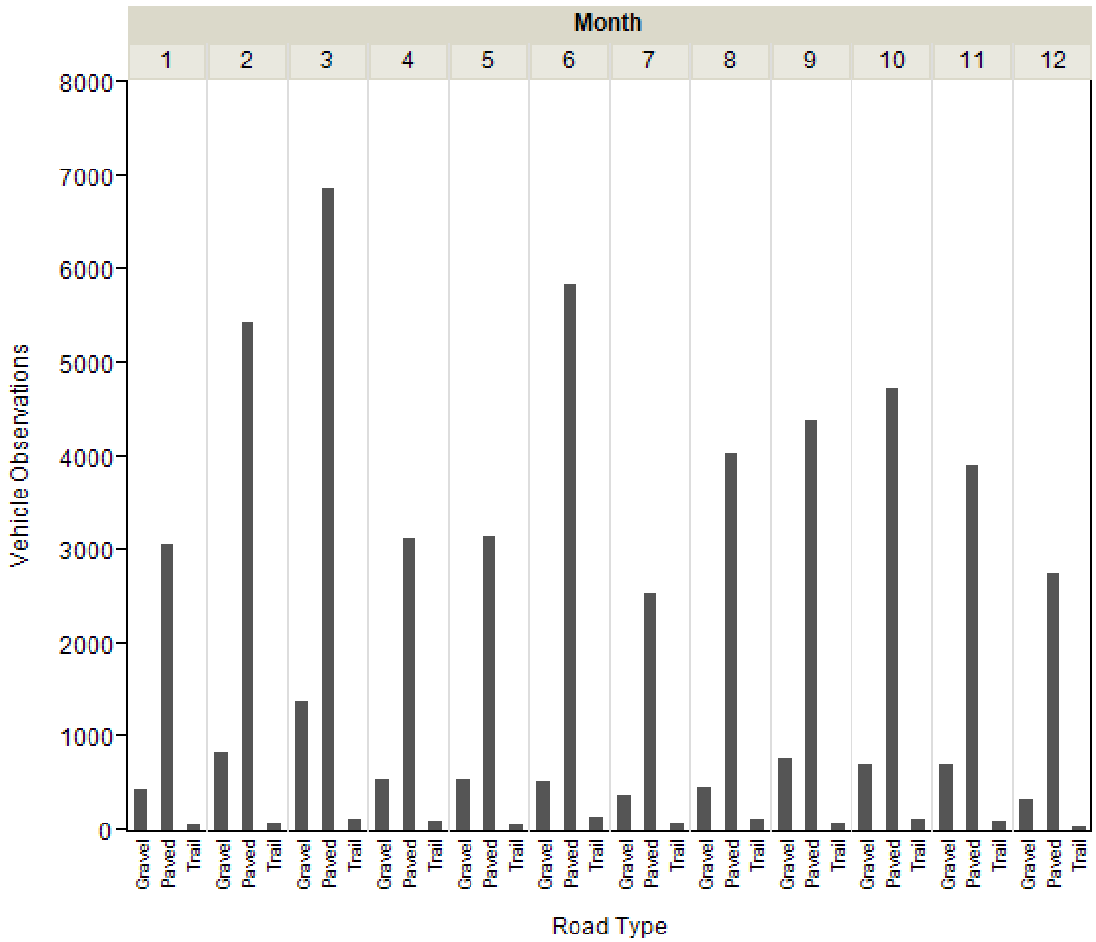

Figure 3. Total vehicle counts by month and road type at Camp Bullis, Texas from March 2012-March 2013.

.

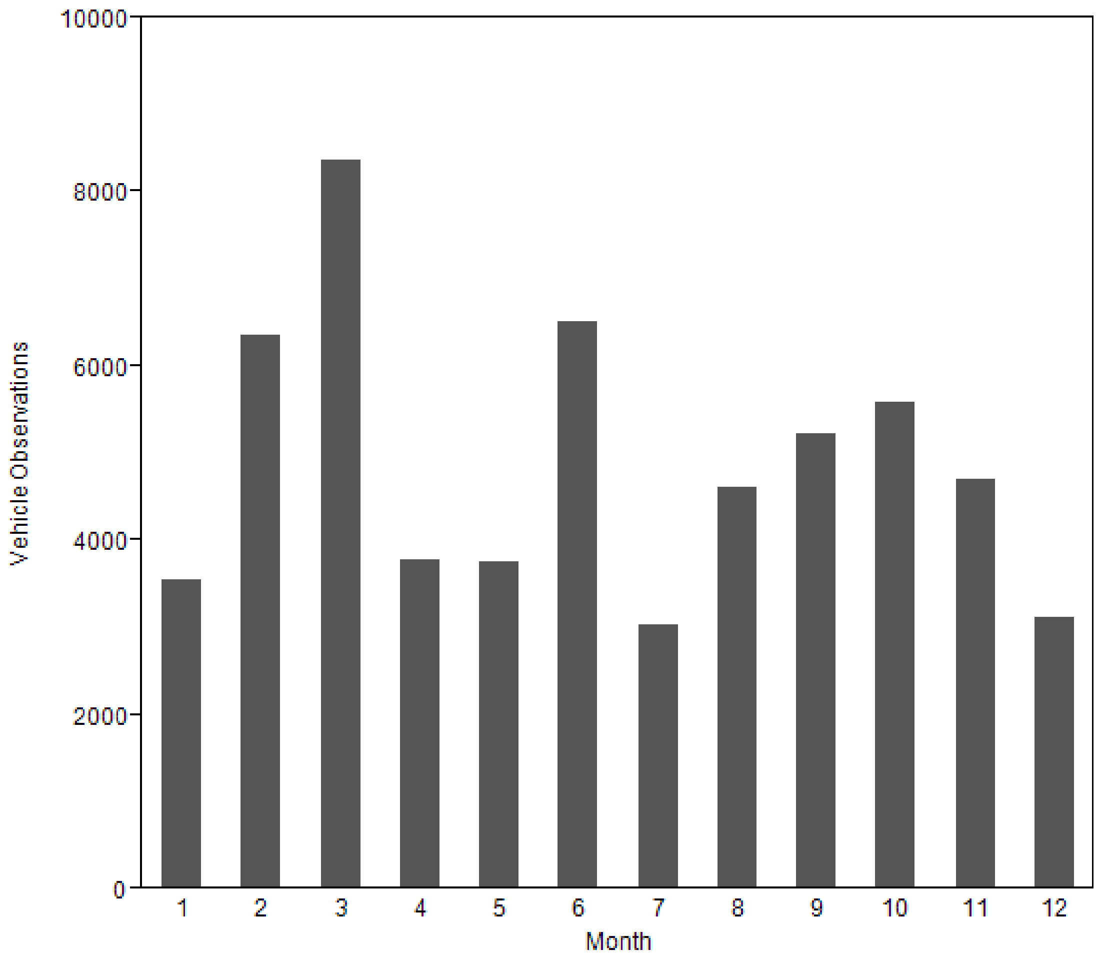

Figure 4. Total vehicle counts by month at Camp Bullis, Texas from March 2012-March 2013.

.

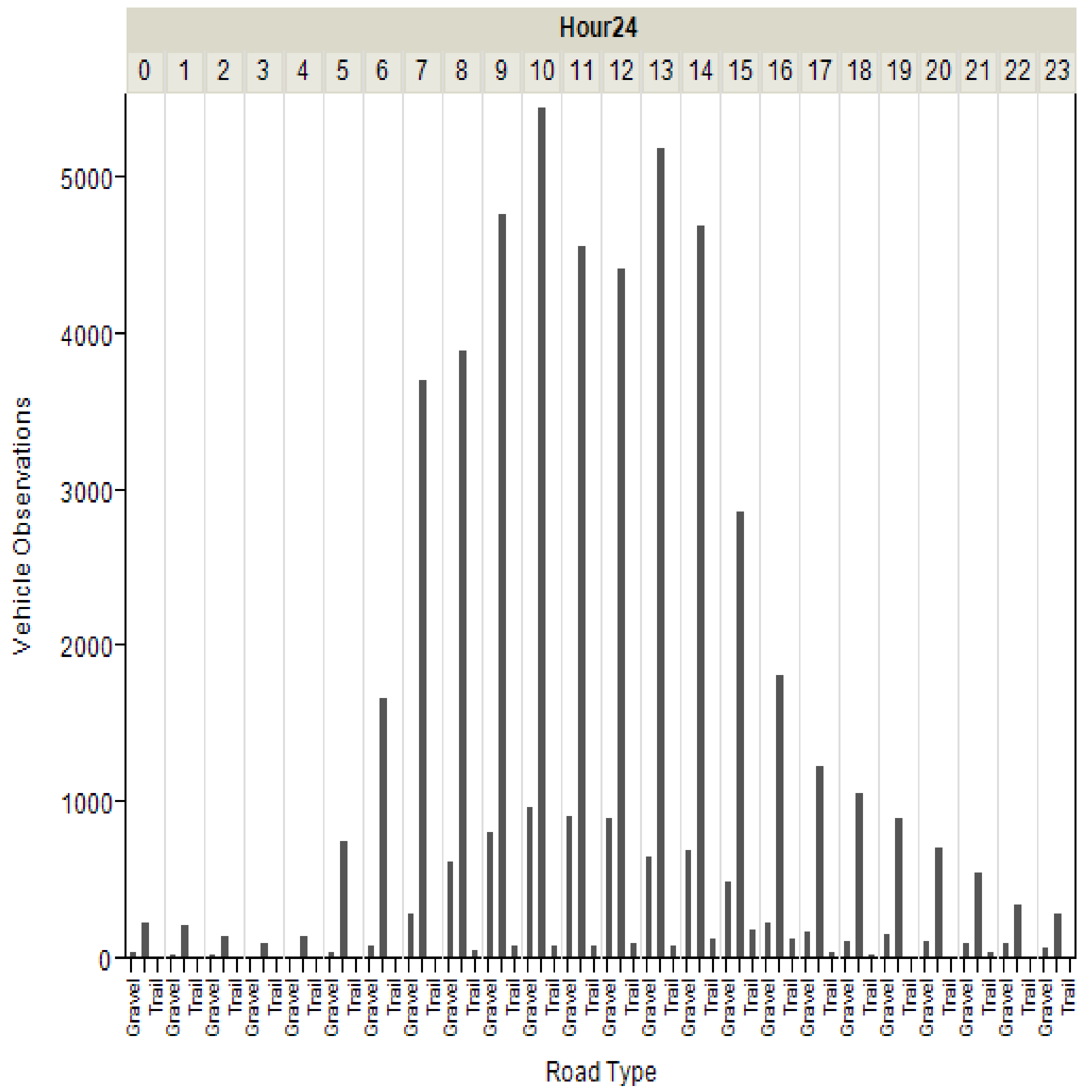

Figure 5. Total vehicle counts by 24-hour period and road type at Camp Bullis, Texas from March 2012-March 2013.

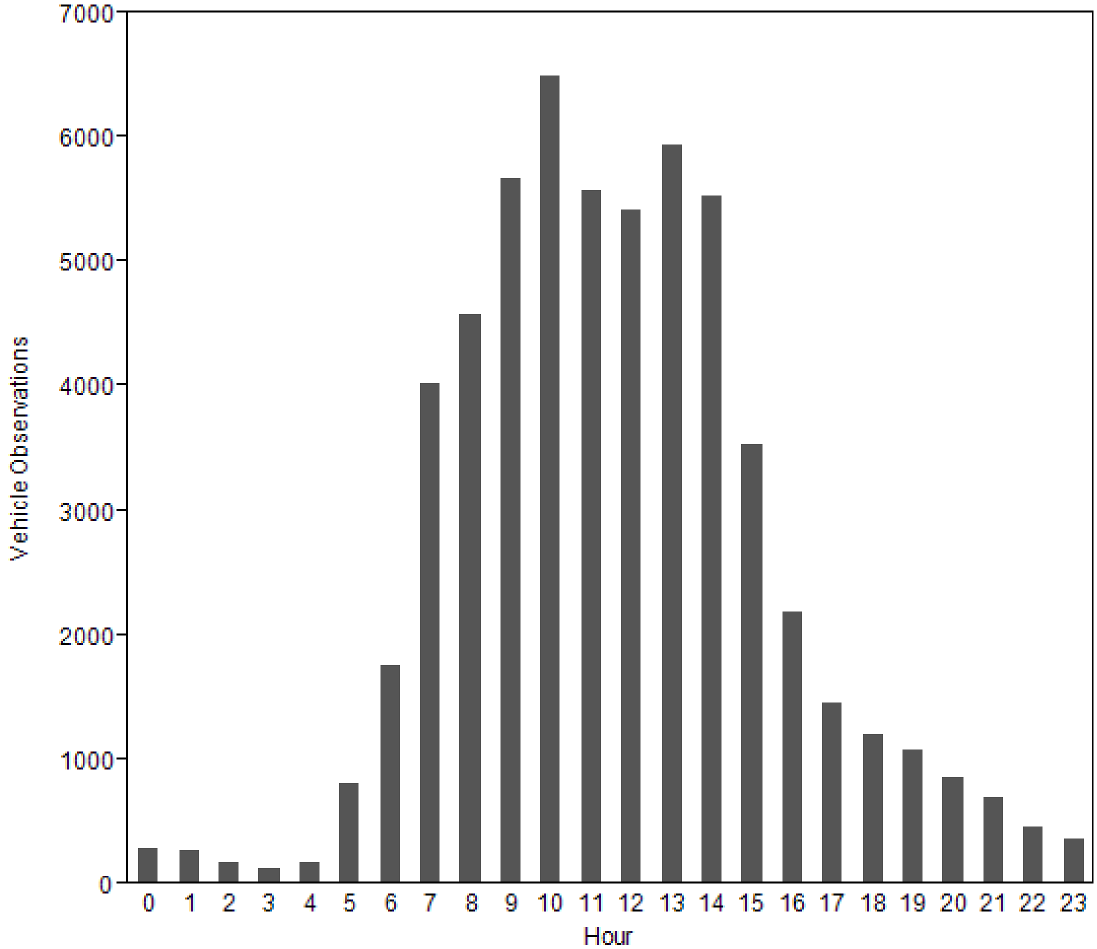

Figure 6. Total vehicle counts by hour at Camp Bullis, Texas from March 2012- March 2013.

.

CHAPTER IV

CONCLUSION

The field study took place over the course of 1 year in order to attain a measure of the traffic activity. Vehicle observations were found to be dependent on the type of road observed. Most of the traffic occurred on paved roads as the military uses these routes to access their training forward operating bases (FOB). The military traveled in convoys consisting of high mobility multipurpose wheeled vehicles (HMMWV), troop transports, and pickup trucks. The majority of these convoys occurred on paved roads to drop off troops and/or supplies for training. Gravel and trail roads were used sparingly as they may cause damage to vehicles and rarely lead to FOBs.

Throughout the year, traffic activity was highest during the temperate months (Fig. 4). A main factor that affects military training is temperature due to internal body temperature maximum and minimum limitations (Schrier 1970). Traffic activity was lowest during the months with the most extreme temperature differences as this could negatively affect training exercises. Traffic varied by hour, but was highest at midday (Fig. 5). Transportation to and from training occurs midmorning and afternoon in convoys. Few training exercises occur in the middle of the night. All of these differences in traffic activity have a potential impact on wildlife management practices.

MANAGEMENT IMPLICATIONS

Camp Bullis conducts their spotlight estimates of white-tailed deer around sunset. This is usually from1800–2000 hours. Paved roads are still being used at this time, and this could potentially affect deer movement patterns as deer are most active during this time period. Spotlight estimates are also conducted along trail and gravel roads. These roads may have a biased estimate due to the extreme traffic along paved roads. The deer may prefer less trafficked road systems, but more data needs to be collected (Anderson 2003). The importance of traffic activity data may not be limited to Camp Bullis.

Traffic activity data could be useful not only in determining ideal times for spotlight estimates, but also for determining the impacts on where birds nest sites, endangered species locations, and distance sampling used to estimate other animal populations (Pitman et al. 2005, Cypher et al. 2009, Erxleben et al. 2011). Collecting traffic data can be tailored to the needs of a specific research project. Infrared-triggered cameras gather more traffic activity data than conventional methods and are cost effective, and save time. Road systems are a reality in every environment and understanding them can only benefit the field of wildlife management.

LITERATURE CITED

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294–1297.

Anderson, D. R. 2003. Response to Engeman: index values rarely constitute reliable information. Journal of Wildlife Management 31:288–291.

Beier, Paul and Dale R. 1990. Factors influencing white-tailed deer activity patterns and habitat use. Wildlife Monographs 109: 3-51.

Brown, J., and S. Gehrt. 2009. The basics of using remote cameras to monitor wildlife. Ohio State University Extension Fact Sheet W-21-09, Ohio State University, Columbus, USA.

Buckland, S.T., D. R. Anderson, K. P. Burnham, J. L. Laake,D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling. Oxford University Press, Oxford, England, UK.

Butler, M. J., M. C. Wallace, W. B. Ballard, S. J. DeMaso, R. D. Applegate. 2005. The relationship of Rio Grande wild turkey distributions to roads. Wildlife Society Bulletin 33:745–748.

Crooks, K. R., M. Grigione, Alison Scoville, Gerald Scoville. 2008. Exploratory use of track and camera surveys of mammalian carnivores in the Peloncillo and Chiricahua mountains of Southeastern Arizona. The Southwestern Naturalist 53:510–517.

Cowardin, L., and J. Ashe. 1965. An automatic camera device for measuring waterfowl use. Journal of Wildlife Management 16:438–441.

Curtis, P. D., and P. G. Jensen. 2004. Habitat features affecting beaver occupancy along roadsides in New York State. Journal of Wildlife Management 68:278–287.

Cutler, T. L., and D. E. Swann. 1999. Using remote photography in wildlife ecology: a review. Wildlife Society Bulletin 27:571–587.

Cypher, B. L., C. D. Bjurlin, and J. L. Nelson. 2009. Effects of roads on endangered San Joaquin kit foxes. Journal of Wildlife Management 73:885–893.

Deb, S. K., and R. K. Nath. 2012. Vehicle detection based on video for traffic surveillance on road. International Journal of Computer Science and Emerging Technologies 3:121–137.

Dickson, B. G., J. S. Jenness, and P. Beier. 2005. Influence of vegetation, topography, and roads on cougar movement in Southern California. Journal of Wildlife Management 69:264–276.

Dodge, W., and D. Snyder. 1960. An automatic camera device for recording wildlife activity. Journal of Wildlife Management 24:340–342.

Dreibelbis, J. Z., K. B. Melton, R. Aguirre, B. A. Collier, J. Hardin, N. J. Silvy, and M. J. Peterson. 2008. Predation of Rio Grande wild turkey nests on the Edwards Plateau, Texas. Wilson Journal of Ornithology 120:906–910.

Engeman, R. M. 2003. More on the need to get the basics right: population indices. Wildlife Society Bulletin 31:286–287.

Erxleben, D. R., M. J. Butler, W. B. Ballard, M. C. Wallace, M. J. Peterson, N. J. Silvy, W. P. Kuvlesky, D. G. Hewitt, S. J. DeMaso, and J. B. Hardin. 2011. Wild Turkey (*Meleagris gallopavo*) association to roads: implications for distance sampling. European Journal of Wildlife Research 57:57–65.

Fiehler, C. M., B. L. Cypher, S. Bremner-Harrison, D. Pounds. 2007. A theft-resistant adjustable security box for digital cameras. Journal of Wildlife Management 71(6):2077–2080.

Franzreb, K. E., and J.L. Hanula. 1995. Evaluation of photographic devices to determine nestling diet of the endangered red-cockaded woodpecker. Journal of Field Ornithology 66:253–259.

Garrison, B. A., R. L. Wachs, T. A. Giles, and M. L. Triggs. 1999. A mounting technique for Trailmaster camera systems to monitor deer. Transactions of the Western Section of the Wildlife Society 35:50–66.

Gould, F. W. 1969. Texas plants - a checklist and ecological summary. Texas A&M University and Texas Agric. Exp. Stn., MP-585/Revised, College Station. 121 pp.

Gysel, L. W., and E. Davis, Jr. 1956. A simple automatic photographic unit for wildlife research. Journal of Wildlife Management 20:451–453.

Heilbrun, R. D., N. J. Silvy, Michael E. Tewes, M. J. Peterson. 2003. Using automatically triggered cameras to individually identify bobcats. Wildlife Society Bulletin 31:748–755.

Heilbrun, R. D., N. J. Silvy, Michael E. Tewes, M. J. Peterson. 2006. Estimating bobcat abundance using automatically triggered cameras. Wildlife Society Bulletin 34:69–73.

Jacobson, H. A., J. C. Kroll, R. W. Browning, B. H. Koerth, and M. H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. Wildlife Society Bulletin 25:547–556.

Jones, L. L. C., M. G. Raphael, J. T. Forbes, and L. A. Clark. 1997. Using remotely activated cameras to monitor maternal dens of martens. Pages 329–349 *in* G. Proulx, H. N. Bryant, and P. M. Woodard, editors. Martes: taxonomy, ecology, techniques, and management, Provincial Museum of Alberta, Alberta, Canada.

Koerth, B. H., C. D. McKown, and J.C. Kroll. 1997. Infrared-triggered camera versus helicopter counts of white-tailed deer. Wildlife Society Bulletin 25:557–562.

Kucera, T. E., and R.H. Barrett. 1993. The Trailmaster camera system for detecting wildlife. Wildlife Society Bulletin 21:505–508.

Laurian, C., C. Dussault, J.-P. Ouellet, R. Courtois, M. Poulin, and L. Breton. 2008. Behavior of moose relative to a road network. Journal of Wildlife Management 72:1550–1557

Liggett, L. E.. 2008. Analysis of seasonal and day-of-week traffic patterns at national parks. Thesis, Texas A&M University, College Station, USA.

Locke, S. L., I. D. Parker, and R. R. Lopez. 2012. Use of remote cameras in wildlife ecology. Pages etc. *in* N. J. Silvy, editor. The wildlife techniques manual, Volume 1: research, Seventh edition, John Hopkins University Press, Baltimore, Maryland, USA.

Long, E. S., D. R. Diefenbach, B. D. Wallingford, and C.S. Rosenberry. 2010. Influence of roads, rivers, and mountains on natal dispersal of white-tailed deer. Journal of Wildlife Management 74:1242–1249.

Lopez, R. R., and N. J. Silvy. 1999. Use of infrared-triggered cameras and monitors in aquatic environments. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 53:200–203.

Mathews, S. M., R. T. Golightly, and J. M. Higley. 2008. Mark-resight population density estimation for American black bears in Hoopa, California. Ursus 19:13–21.

McGowen, P., and M. Sanderson. 2011. Accuracy of pneumatic road tube counters. Western District Annual Meeting, Institute of Transportation Engineers, Anchorage, Alaska, USA.

Newbery K, K., and C. Southwell. 2009. An automated camera system for remote monitoring in polar environments. Cold Regions Science and Technology 55:47–51.

Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. The Journal of Wildlife Management 69:1259–1269.

Progulske, D. R., and D. C. Duerre. 1964 Factors influencing spotlighting counts of deer. Journal of Wildlife Management. 28:27–34.

Ribic, C. A., F. R. Thompson, III, and P. J. Pietz, editors. 2012. Video surveillance of nesting birds. University of California Press Berkeley and Los Angeles, California, USA.

Rice, C. G. 1995. Trailmaster camera system: the dark side. Wildlife Society Bulletin 23:111–113.

Richardson, D. M., J. W. Bradford, P. G. Range, and J. Christensen. 1999. A video probe system to inspect red-cockaded woodpecker cavities. Wildlife Society Bulletin 27:353–356.

Roberts, C. W., B. L. Pierce, A. W. Braden, R. R. Lopez, N. J. Silvy, P. A. Frank, and D. Ransom, Jr. 2006. Comparison of camera and road survey estimates for white-tailed deer. Journal of Wildlife Management 70:263–267.

Schrier, Robert W., Jesse Hano, Howard I. Keller, Richard M. Finkel, Paul F. Gilliland, W. J. Cirksena, P. E. Teschan. 1970. Renal, metabolic, and circulatory responses to heat and exercise studies in military recruits during summer training, with implications for acute renal failure. Annals of Internal Medicine 73(2):213-223.

Skszek, S. L. 2001. "State-of-the-art" report on non-traditional traffic counting methods. "http://ntl.bts.gov/DOCS/arizona_report.html". Arizona Department of Transportation, Phoenix, USA.

Swann, D. E., C. C. Hass, D. C. Dalton, and S. A. Wolf. 2004. Infrared-triggered cameras for detecting wildlife: an evaluation and review. Wildlife Society Bulletin 32:357–365.

Taylor, F. B., R. B. Hailey, and D. L. Richmond. 1966. Soil survey of Bexar County, Texas. Publication number 12, U.S. Soil Conservation Service, Department of Agriculture, San Antonio, Texas, USA.

Thome, D. M., and T. M. Thome. 2000. Radio-controlled model airplanes: inexpensive tools for low-level aerial photography. Wildlife Society Bulletin 28:343–346.

Van Auken, O. W., A. L. Ford, and A. Stein. 1979. A comparison of some woody upland and riparian plant communities of the southern Edwards Plateau. Southwestern Naturalist 24:165–180.

Van Auken, O. W., A. L. Ford, A. Stein, and A. E. Stein. 1980. Woody vegetation of upland plant communities in the southern Edwards Plateau. Texas Journal of Science 32:23–35.

Van Auken, O. W., A. L. Ford, and J. L. Allen. 1981. An ecological comparison of upland deciduous and evergreen forests of central Texas. American Journal of Botany 68:1249–1256.

Wang, G., D. Xiao, and J. Gu. 2008. Review on vehicle detection based on video for traffic surveillance. Pages 2961–2966 *in* Automation and Logistics. IEEE International Conference on 1-3 September, 2008.